GEOLOGY AND ORE DEPOSITS OF THE RICHMOND BASIN AREA
GILA COUNTY, ARIZONA

by

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O. M. B.

SUMMARY

Richmond Basin Mining District, which lies ten miles north of Globe, Gila County, Arizona, is an old mining camp which was a prominent silver producer fifty years ago. Although the total production has been less than one million dollars, the richness of the ores drew considerable attention to the district.

The oldest rock in the Basin is the pre-Apache Ruin granite, which forms the basement rock of the region. Upon an old erosion surface of this rock the Apache group of sediments was deposited. This group has at its base the Scanlan conglomerate, which is overlain by the Pioneer formation, the basal 270 feet of which are arkosic and probably continental in origin; its upper member was evidently deposited under shallow water conditions. Overlying the Pioneer shale is the Barnes conglomerate, which in turn is overlain by the Dripping Spring quartzite. Following the deposition of these formations in Proterozoic and still in pre-Cambrian time, the sediments were subjected to stresses which caused the formation of an anticline. The anticline was faulted along its strike and intruded by a great dike of diabase, which spread laterally as sills into the arkosic member of the Pioneer shale. Subsequent to the diabasic intrusion there was faulting parallel to the intrusive, both within the intrusive and in the sediments on each side. In Mesozoic or Tertiary (?) time, andesite porphyry was intruded upward through one of the fault fissures, and invaded the Dripping Spring quartzite as a sill.

In the southeastern part of the area there is a mass of quartz diorite that has been intruded into the diabase dike.

The ore deposits that followed the quartz diorite intrusion have two occurrences. They are:

(1) Ore deposits on the contact of the Scanlan conglomerate.

(2) Ore deposits that occur as veins in fault fissures.

The ores of both these groups consist of primary chalcopyrite, argentite and tennantite, together with secondary native silver and silver halides.

INTRODUCTION

FIELD WORK

The field work upon which this report is based was done during the summer and fall of 1934. A base map of the area was made during August, and the geologic mapping was done over a period of two weeks in November and December of that year.

Previous investigation of the district has been very limited. Dr. F. L. Ransome (1) visited the Basin in 1901, at the time he was doing the field work on the copper deposits of the Globe Quadrangle. In discussing the Apache group, he gives a stratigraphic section of the Apache Mountains which extends through Richmond Basin.

N. H. Darton, (2) while preparing the bulletin, Resume of Arizona Geology, evidently made a brief reconnaissance survey of the district, as he also gives some descriptive data on the sedimentary relationships in the area.

LOCATION

The Richmond Basin mining district is situated ten miles north of Globe on the south ~~northwest~~ slope of the Apache Mountains. This range is one of the northwesterly trending series which lie in the mountainous belt of Arizona.

The roads which were built during the camps activity have long since fallen into disuse, and now, the best

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(1) Ransome, F. L., Geology of the Globe Copper District, Arizona, U. S. Geol. Survey, Prof. Paper 12, 1903.

(2) Darton, N. H., Resume of Arizona Geology, Arizona Bureau of Mines Bulletin No.119, 1925.

approach to the area is by the road up Copper Gulch from Globe, past the now abandoned Superior and Boston Mine, and thence over an ungraded and little worked road to within a half mile of the mapped area. From there the district is reached on foot. The new section of U. S. Highway 60 passes within 4 miles of Richmond Basin, and the nature of the terrain is such that a road from the highway to the Basin could be built and maintained much more cheaply than by the present route.

HISTORY AND PRODUCTION

Mining in the Richmond Basin district began in 1875, when silver nuggets were first discovered along Nugget Gulch.(3) Patrick Hamilton, in writing The Resources of Arizona, said:

> The wonderful richness of the ores shipped in the early days of its discovery created a furor all over the coast. Tons and tens of tons, sent to San Francisco, went from $1000 to $20,000 per ton.

At that time the McMorris Mine had been sunk to a depth of 800 feet, and had produced over $700,000. At the same time it was estimated that nearly $100,000 in native silver had been picked up as nuggets in Nugget Gulch. Richmond Flat was everywhere dotted with open-cuts and shafts which extended down to the mineralized contact of the basement granite with the overlying formation. A ten-stamp mill was kept running constantly on Pinal Creek, five

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(3) Hamilton, Patrick, The Resources of Arizona, A. L. Bancroft and Co., San Francisco, 1883, p. 207.

miles to the west. The territorial geologist, W. P. Blake, wrote in 1895: (4)

> The silver is found as chloride mixed with huge masses of native silver, and carbonates, some embolite, and vanadinite mixed with it. The whole mass is usually associated with hematite, and is invariably free from gold.

In the same report there is illustrated a 31-pound nugget from the area which was found in August of 1895.

Production since the early days of the district has largely declined. This is due primarily to the exhaustion of the bonanza ore shoots and secondly to the lower market value. By 1885 the best of the ore was taken, and production had declined greatly. The Bland-Allison Act of 1878 and the Sherman Act of 1890 encouraged exploration in the district, but with the repeal of the Sherman Act in November of 1893, and the decline in value, all mining activity except that of a few lessees and prospectors ceased.

Among the prospectors who have worked steadily and courageously in the Basin are the Newbould brothers. (5) In 1917 they together with William Pohl took approximately $6,000 from the Jumbo Lead. They sold their interests in 1917 to a Texas corporation which shipped ore to the value of $48,000. At that same time while silver was worth well over a dollar per ounce, an effort was made to re-timber the old McMorris shaft and do exploration work in the mine. The effort was abandoned after getting down to the 200-foot level. In 1918, the Gila Monster Mining Co. built a 5-stamp

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(4) Blake, W. P., Mining in Arizona, Report of Governor to the Secretary of the Interior, 1899, pp. 43-109.

(5) Personal communication from J. D. Newbould, August, 1934.

mill in the Basin for the purpose of reworking the old mine dumps of the McMorris and Richmond Mines, but as the mill failed to pay it was soon shut down.

At present there are three active claims in the Basin. Mr. William Wyte, in the spring of 1934, mined 800 pounds of ore from a prospect in the lower part of Nugget Gulch, for which he received $1200 from the smelter. The Newboulds are mining a small quantity of high grade ore from one of their claims on the flat southwest of the McMorris shaft; and William Ikenberry, who is leasing from the Newboulds is obtaining similar small amounts of high grade silver ore from his workings.

Production has not been increased by more than $100,000 since the eighties making the total production from Richmond Basin slightly less than $1,000,000.

SUPERFICIAL FEATURES

BROAD TOPOGRAPHIC FEATURES

The mountains and the accompanying valleys which make up the topographic forms in the region of Richmond Basin owe their existence chiefly to differential erosion, faulting, and intrusion.

The topography is one of bold relief, such as is characteristic of youthful erosion. The sediments of the Apache group have differentially eroded so that the resistant Dripping Spring quartzite forms the high

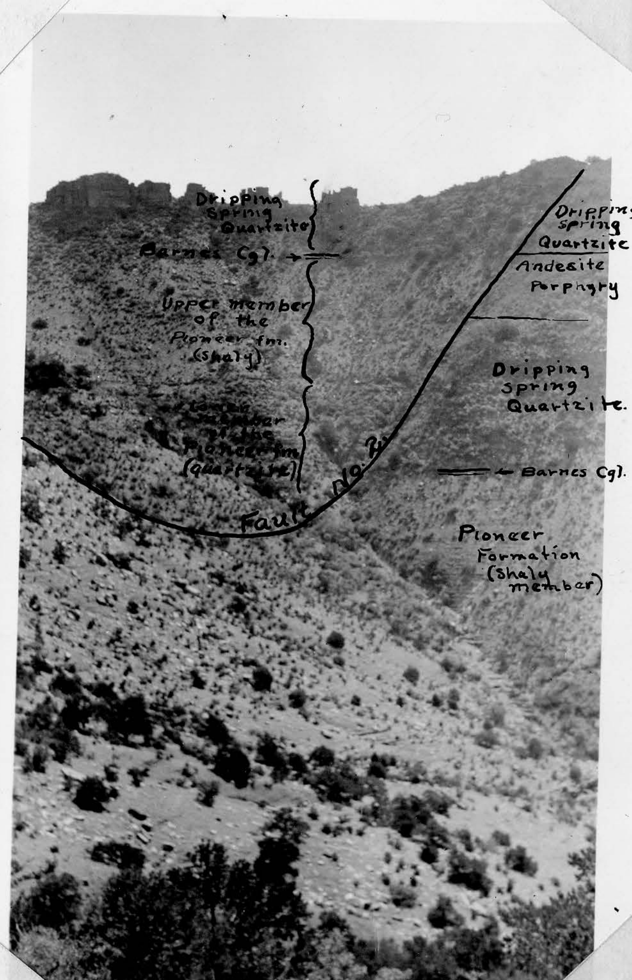

Fig. 1.

peaks. The upper member of the Pioneer shale which underlies the Dripping Spring quartzite is much less resistant so that it forms a steep, but much smoother slope. Below the upper shaly member of the Pioneer is the lower arkosic quartzite (See Fig.2.) member of the Pioneer formation. It forms a steep rough slope as can be seen from the photograph.

Lower still on the slope is a 50-foot cliff of Ruin granite. Beneath the cliff is diabase, which weathers to form a uniform but steep slope that extends down to the Basin floor. At the base of this latter slope the silicified contact of the Scanlan conglomerate and the Ruin granite offers such resistance that there is a considerable area whose surface almost coincides with the silicified contact.

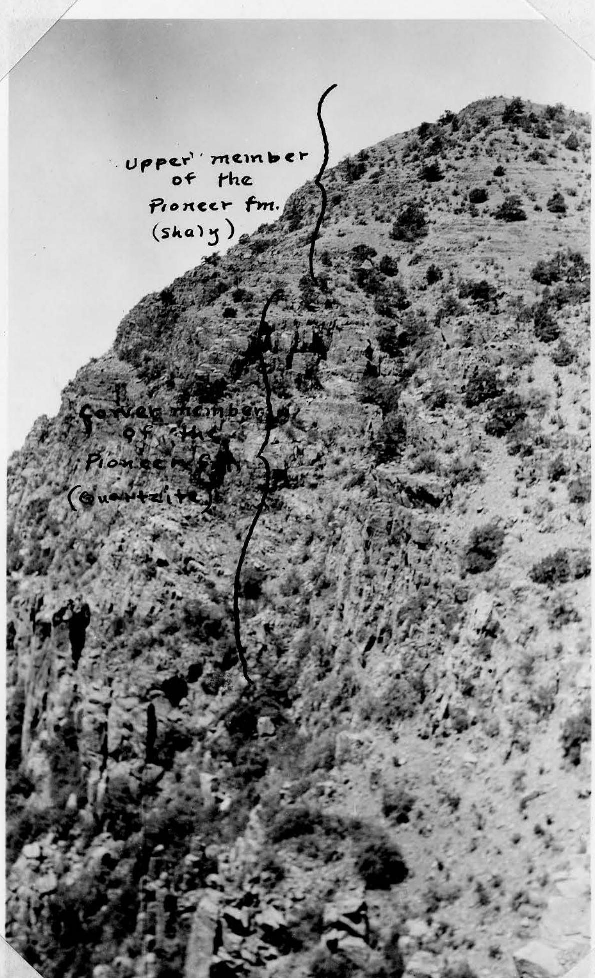

Fig. 2.

Looking out to the south and west from the Basin, one sees an old high-level valley floor which is composed of Quaternary Gila conglomerate. With the most recent uplift that the region has undergone, the stream gradient has been increased, and erosion is once more actively removing material so as to make a youthful valley within the older mature Quaternary valley. Everywhere over the expanse which is seen stretching along the northeast slope of the Pinal Mountains as far as the town of Miami and thence northward holding against the mountainside, the gentle slopes of the mature valley rise above the sharp, steep sides of the younger one and its tributaries.

The Apache Mountains, as has been said, are composed of the nearly flat-lying Apache group of sediments which rest unconformably upon the old pre-Cambrian granite. From the summit of Apache Peak looking eastward over Seven Mile Draw, one sees first the Timber Camp and Seven Mile Mountains and still beyond the broad expanse of the Natanes Plateau. Both the mountains and the plateau are part of the same structural unit as are the Apache Mountains.(6) In each case they consist of the Apache series lying unconformably upon pre-Cambrian granite. Although faulting has outlined these elevated masses somewhat, they are separated chiefly because of erosion, the Apache Mountains at one time being a part of the plateau as were the Seven Mile and Timber Camp Mountains.

CLIMATE AND VEGETATION

The climate of Richmond Basin is delightful. Because of its southern exposure the winters are mild and yet because of its altitude the summers are never oppressively hot.

The vegetation is that usually found in central Arizona between five and seven thousand feet. A diversity of cacti, including several varieties of cholla and opuntia, is found in the lower portions of the area.

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(6) Darton, N. H., Op. Cit.,pp. 243-244.

Yuccas and agaves are distributed more widely, and the thorny shrubs, such as mesquite, and acacia (catclaw), abound in the Basin. The upper slopes are largely barren of vegetation because of the intense erosion.

GENERAL GEOLOGY

SUMMARY

The general relationships of the formations in the Apache Mountains and at Richmond Basin may be seen from the geologic sections of Plate II. At the base is the pre-Cambrian Ruin granite. It was subjected to long-continued erosion which reduced it to a peneplane before the deposition of the Scanlan conglomerate.

Overlying the granite is a series of pre-Cambrian sediments which extend in conformable sequence to the top of Apache Peak, the highest elevation in the area. These are from bottom to top, the Scanlan conglomerate, the Pioneer formation, and the Dripping Spring quartzite.

The Mescal limestone which is the topmost member of the Apache group as described in the Globe[7] and adjacent districts is missing in Richmond Basin but is found a mile and a half south of the mapped area.

The Paleozoic sediments which occur in the Globe quadrangle are likewise absent.

Intrusive into the Ruin granite and Apache group are several sills and one dike of diabase. This rock[8] is widespread in central Arizona and is found over an area of at least 1600 square miles.

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(7) Ransome, F. L., Op. Cit.

(8) Short, M. N., and Ettlinger, I. A., Ore Deposition and Enrichment at the Magma Mine, Superior, Arizona: Trans. Amer. Inst. of Mining and Met. Engineers. Vol.74, p.181.

In the southeastern portion of the mapped area a quartz diorite stock intrudes the Ruin granite and the diabase. This intrusive has considerable extent to the south and east.

The youngest rock in the area is an andesite porphry which has intruded the upper part of the Dripping Spring quartzite as a sill, and occurs as a dike in the diabase.

After the intrusion of the diabase, faulting occurred which is of at least two different ages. It is in one of these faults that the chief mineralization is found.

GEOLOGICAL FORMATIONS

Pre-Cambrian Rocks

Ruin Granite

The oldest rock in the Richmond Basin region is the Ruin granite, which Ransome[9] describes in the Globe report. It underlies the entire Apache Range, being the foundation or basement rock on which the Apache group was laid down. The surface of the Ruin granite, wherever exposed, is that of a very uniform plain.

The granite characteristically weathers to a gravel of quartz and feldspar. It is a coarse-grained pink rock, the color being due to the preponderance of orthoclase phenocrysts, some of which have a length of

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(9) Op. Cit., p.59.

five centimeters, although the average length is one and a half centimeters. The ferromagnesian mineral constituent is highly altered, and is now represented by limonitic material.

Microscopic study shows 65 per cent of the section to be orthoclase which is undergoing incipient sericitization. No other feldspar was found in the two sections studied although Ransome found microperthitic microcline and some sodic plagioclase in the Ruin granite that he describes. The crystals of feldspar are traversed by cleavage cracks which are filled in part with quartz and in part with pleochroic serpentine. Occurring along these same cleavage cracks are also grains of hematite which are very likely secondary after magnetite. Biotite which is the primary ferromagnesian has been altered to serpentine, chlorite, magnetite, and hematite. Quartz grains averaging 6 millimeters in section comprise about 20 per cent of the rock sections examined.

The contact between the Scanlan conglomerate and the granite looks very much like an igneous one at first inspection. Fragments of feldspar and quartz which are sub-euhedral in outline are found between the pebbles of the Scanlan conlomerate in such a manner as to suggest intrusion; the singular lack of the usual cementing material and of all the pebbles but quartzite suggest the absorption of the matrix and most of the pebbles by an intruding rock. Closer examination over more areal extent however shows the true relationship to be that of an unconformable sedimentary contact. This conclusion was based upon two lines of reasoning, one of which supports a hypothesis of sedimenary contact and the other of which refutes the intrusive hypothesis. The latter will be considered first.

1. The contact is not irregular or warped or broken as would be expected in the case of an intrusive contact.
2. No fragment of either the Scanlan conglomerate or the Pioneer formation could be found within the granite near the contact.
3. Along the mile and a half of contact that was examined, no apophysis of the intrusive within the country rock could be found.
4. The metamorphism which is found in the Scanlan and Pioneer formations is explained by the nearness of the diabase and the regional metamorphism that was attendant upon the overlying load and later diastrophism.

Reasons for considering the contact as a sedimentary one are:

1. The contact is comparatively uniform, and conforms with the stratification of the Apache group.
2. The fragments of feldspar that occupy the space between the Scanlan pebbles are never as long as the ones found a foot or so below the contact, although they may be as large in cross-section. In many instances they are somewhat rounded and worn, suggesting that they are a detrital accumulation

that has weathered free from the granite but remained in place. On the gently sloping hills just south of the Basin, the Ruin granite weathers out into such material; it is coarse and equi-dimensional, being very similar to the material found at the contact, except that it is unconsolidated. On a slope of 10 to 15 degrees this gravel accumulates to a depth of several inches, and it is probable that on a peneplaned surface of granite such as the lack of relief shows to have existed, the detritus might have accumulated to a depth of several feet. Assuming this to be so, one can easily see how this material was concentrated. The pebbles of the Scanlan conglomerate settled down into the detritus, and then when later material was deposited upon it, the temperature increased due to the depth of burial and the intrusion of the diabase, and the interstitial water became increasingly active chemically and brought about the consolidation which converted the granitic debris into a well-cemented arkose.

Scanlan Conglomerate

The Scanlan conglomerate which directly overlies the Ruin granite is a continental deposit that has been laid down upon the ancient surface and its mantle of arkosic gravel. Ransome,(10) who was the first to describe the Scanlan conglomerate, interpreted the formation as having undergone but little transportation. In the

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(10) Op.Cit., pp.30-31.,

Ransome, F. L.,Copper Deposits of Ray and Miami,Arizona, U. S. Geol. Survey,Prof.Paper 115, pp.39-40.

Globe report it is described as being

> from 1 to 6 feet thick and ....composed of imperfectly rounded pebbles of vein quartz.... held in a pink arkosic matrix .... The conglomerate is extremely variable both in constitution and in thickness..... where it rests on granite or quartz-mica diorite the pebbles are likewise mostly quartz, but the matrix is mostly arkosic and the layers of pebbles may be associated with beds of arkose that in many places merge imperceptibly with the underlying massive rock or grade upward into the Pioneer shale.

how about quartzite?

This description in general fits the occurrence at Richmond Basin. The Scanlan conglomerate is quite variable, ranging from 0 to 9 feet within the area mapped. It is made up chiefly of white to pink or gray quartzite pebbles, but locally one finds vein quartz and jasper pebbles. They vary from one-half inch to 8 inches in diameter, the larger ones invariably being quartzite; all except the chert are imperfectly rounded, suggesting the origin to be quite near the place of deposition. In some places the Scanlan is entirely missing and the Pioneer formation rests directly upon the granite.

Pioneer Formation

over 600' thick what is it at ledges?

Above the Scanlan conglomerate is the Pioneer formation which is particularly well represented in Spring Canyon. The basal member of the Pioneer formation consists of 265 feet of arkosic quartzite which forms the steep cliffs of the mountainside. (See Fig.2.) The intrusion of the diabase together with the regional metamorphism attendant upon folding has greatly altered the sediments.

The original silica has been reworked, and perhaps some added. In addition to quartz which forms about 35 per cent, the rock is made of sericite and hematite. The rock is highly indurated with a speckled appearance due to hematite flakes scattered through a gray-green rock. It was this rock that Ransome (11) suggested calling the Scanlan quartzite. Inasmuch as this report concerns a limited area, it was considered best to make no division of the accepted formations.

The lower quartzite member grades into an upper and more shaly member which is the typical Pioneer shale. It is an arenaceous, less indurated, thin-bedded shale of varying shades of red, brown, and purple, giving the entire formation a dark red to purple color. Lausen (12) writes of the Pioneer shale that with depth(in the Iron Cap Mine, Globe) away from oxidation influences, the color is greenish or various shades of gray with a greenish tinge, and that the small, elliptical or round spots of light green to buff that are abundant in the surface occurrence are entirely absent. The spots which are so common in the upper member of the formation in Richmond Basin are explained as being due to local concentrations of organic material which have kept the rock from being oxidized within their zone of influence. The upper formation is 395 feet thick.

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(11)Ransome, F.L.,Geology of the Globe Copper District, Arizona.: U. S. Geol. Survey, Prof. Paper 12, p.37.

(12)Lausen, Carl, The Geology of the Old Dominion Mine: Master's Thesis at the Univ. of Arizona, 1923, p. 8.

It is thought that the lower member of the formation is of land origin, but that the upper shaly member was deposited in shallow water. Whether it was marine or fresh water is not known as there are no fossils by which the matter can be determined. If the gray-green color of the beds at depth imply ferrous iron, the clay minerals that compose it must have been deposited under reducing conditions.

Barnes Conglomerate

The Barnes conglomerate, the next member of the stratigraphic column, lies so as to appear conformable with the underlying Pioneer formation and the overlying Dripping Spring quartzite. The Barnes conglomerate, where exposed, is quite uniform in both thickness and composition, although it represents a different facies than any hitherto described. In the upper reaches of Spring Canyon, where it is best exposed, the pebbles form not more than a third of the entire formation. The pebbles range in size from three fourths of an inch to 6 inches, being smaller than those in the Barnes conglomerate in other areas. The matrix of the Barnes found in Spring Canyon is a white to pink arkose which is less strongly cemented than in specimens from other localities. Not only are the pebbles smaller, but the formation is thinner; nowhere does it exceed 4 feet.

Dripping Spring Quartzite

The lower beds of the Dripping Spring quartzite are somewhat conglomeratic and similar to the Barnes conglomerate just described. The first 12 feet are composed of cross-bedded arkose, which contains several small lenses of pebbles. Next above this is 37 feet of interlayered shale and arkose which is cross-bedded and contains occasional pebbles. The shale of this 37-foot formation is similar to that of the upper Pioneer member, in that it also contains the same bleached elliptical spots. These field relationships suggest that Pioneer conditions were interrupted by the deposition of the Barnes conglomerate and the basal member of the Dripping Spring formation, but that they returned for a short time before finally yielding to Dripping Spring conditions.

Above the shale beds are quartzite beds which are typical of the Dripping Spring formation. It is composed of uniform beds of buff and pink quartzite which forms the crenulated crests of the highest peaks of the Apache Range. Erosion has removed the upper beds of the formation so that only 230 feet remain. In the Globe quadrangle the total thickness of the formation is 400 feet.

Thin section study of the upper member shows it to be made up almost entirely of uniformly rounded grains of quartz. Secondary quartz has been introduced as the cementing material between the grains of primary quartz.

Hematite occurs in amounts great enough to give the formation a red color.

Diabase

Diabase is wide-spread in the Richmond Basin both in the form of sills in the Pioneer formation and as a dike that has come up along the front of the Apache Mountains.

In the northwest portion of the area where the mild relief has allowed weathered diabase to accumulate, a dark olive-green soil results. Scattered through it are nodular masses ranging from very small to a foot or more in diameter; they represent material that is more resistant to weathering.

The sills in the Pioneer formation to the south and west of the intrusive are composed of a tough, dense, greenish-black rock which is usually so fine-textured that no mineral but plagioclase can be discerned. To the north and east the diabase does not occur as sills in the Pioneer formation, but rather it has effected a wide-spread metamorphism in the lower arkosic member of the Pioneer formation. The difference in the effect of the diabase on the Pioneer formation on opposite sides of the fault is understandable since the fault is prior to the intrusive. The throw of the fault is down on the southwest and has caused the beds of the Pioneer on that side to be opened by the drag of the fault, whereas to the northeast the fault movement tended to close the beds along the bedding planes, so as not to allow ingress of the diabase.

The diabase in the dike very closely resembles that described in the lower horizon to the west and south of it. In places it is cut be finer-textured diabase, aplite dikes, and also pegmatitic facies of diabase which show large tabular feldspars upon the weathered surfaces.

Thin section study shows the diabase from the southwest of the dike and in the dike to have the ophitic texture which is due to the crystallization of plagioclase before that of the interstitial ferromagnesian mineral. The feldspar, which makes up 60 per cent of the rock, is labradorite of composition $An_{54}Ab_{46}$. The remainder of the rock is made up almost entirely of hornblende, biotite, and magnetite, all of which were formed by replacement of pyroxene. These minerals occur in aggregates that conform in outline with the general form of pyroxene. The hornblende comprises about 20 per cent of the entire rock, and may be as much as 0.5 millimeters in section. Biotite, which is later than the hornblende, magnetite, and small amounts of apatite and epidote make up the remainder of the rock.

The nodular, more resistant pieces of diabase that are found in the canyons and residual diabasic soil were examined microscopically, to learn how they differ from the more easily weathered diabase, It was learned that there is a relatively higher concentration of plagioclase than is usual. In nodules studied by Ransome (13.) the

(13) Ransome, F. L., Copper Deposits of Ray and Miami, Arizona: U. S. Geol. Survey, Prof. Paper 115, p. 54.

greater resistance was thought to be due to a concentration of augite, while Lausen,[14] in a similar study, concluded that the form and the resistance to disintegration is due to closely spaced interlocking feldspar laths with but very little augite between them. These findings suggest that any concentration, either of ferromagnesian or of feldspar, will result in a more resistant mass.

In the basal arkosic beds of the Pioneer formation, the diabase has brought about considerable alteration. Although the bedding-plains were closed by the fault movement, their porous nature allowed hydrothermal solutions to enter freely, so that now the beds are a mass of highly sericitized feldspar accompanied by quartz and hematite. In addition to this effect in the porous beds of the Pioneer formation, there has been much induration and baking of the more shaly beds.

Mesozoic or Tertiary Rocks

Quartz Diorite

Intruding the diabase in the southeastern part of the district is quartz diorite which extends southeastward along the front of the Apache Mountains to

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(14) Op. cit. p. 12.

dacite?

form a small stock. As seen in the field the rock is uniform gray with medium texture. It is essentially an even-grained aggregate of hornblende and plagioclase with considerable amounts of biotite.

Detailed petrographic study shows the section to be about 70 per cent andesine feldspar of composition $Ab_{56}\ An_{44}$. Many of the feldspars show zoning and in them there may be incipient sericitization in the inner zones. Orthoclase makes up about 5 per cent of the section. The dominant mafic mineral which makes up approximately 15 per cent of the section is pleochroic hornblende which o occurs as well defined euhedral crystals which average 1 millimeter in length with an occasional maximum of 2 millimeters. Biotite phenocrystsscomparable in size to those of the hornblende occur to a limited extent; they contain no radioactive halos such as would suggest zircon. Magnetite and quartz make up almost all of the remainder. Both are primary, the rock being fresh and unaltered.

Andesite Porphry — photo of diabase?

The youngest rock in the Richmond Basin area is the andesite porphry. This rock has its chief occurrance in a 50-foot sill in the Dripping Spring quartzite, but in the northwest portion of the mapped area there is a dike of the same rock. Since it cuts the lower granite, the Scanlan conglomerate, the Pioneer formation and the diabase, it is probable that it might have been the feeder for the sill in the Dripping Spring quartzite.

The dark gray color of the porphry in the sill is due to the gray of the groundmass which constitutes about 60 per cent of the rock, and the almost equal distribution of hornblende and feldspar which comprise the remainder. The hornblende phenocrysts are the most distinctive feature of the rock, averaging about 2.5 millimeters in length with a maximum of 7 millimeters. The feldspar lacks good cleavage and appears quite altered.

In the andesite porphry dike the phenocrysts constitute only 10 per cent of the rock in contrast to the sill in which they constitute 40 per cent. Other than this and the greater alteration of the dike-rock, the two occurrences are very similar. In thin section, the rock of the sill consists almost wholly of euhedral crystals of hornblende and andesine in a groundmass of fine andesine and quartz that have been largely altered to chlorite and calcite. A section from the dike,while very much altered, shows feldspar of characteric andesine outlines, and the ferromagnesian is also hornblende, although there are lesser amounts of biotite. These last two have been largely altered to chlorite, titanite, and leucoxene.

The age of the quartz porphry and of the andesite porphry are tentatively placed as Mesozoic or

Tertiary in age. It may be that they may be correlated with similar rocks in the Ray region which Ransome[15] regarded as being of late Mesozoic or early Tertiary age.

(15) Ransome, F. L., Copper Deposits of Ray and Miami, Arizona: U. S. Geol.Survey, Prof. Paper 115, pp. 87-88.

STRUCTURES

SUMMARY

The Apache Mountains owe their prominence in part to erosion, which separated them on the northeast from the Timbercamp and Seven Mile Mountains as well as from the Natanes Plateau. To the southwest, however, they are outlined by normal faults, which have been the chief cause for the relative difference in elevation.

The structures of Richmond Basin may be given under three headings. They are:

1. A northwesterly faulted anticline.
2. Normal faults paralleling the anticlinal structure.
3. Normal faults radial to the anticline.

NORTHWESTERLY FAULTED ANTICLINE

Of the three structures common to the Basin, the faulted anticline is the most important. A dike of diabase, which varies from 1600-2000 feet in width, outlines the crest of the anticline and forms the lower third of the slope from the flats up to the summit of the peak. To the northwest of the dike and on the northwest limb of the structure, the sediments dip N 12°-15°E, but to the southwest on the southwestern limb, the dip is S 5°-10°W.

The faulting which has displaced the Apache series along this anticline totals 670 feet.

All of this movement was not prior to intrusion, however, as there are at least two faults paralleling the dike and within it. An examination of

Plate II will show the anticlinal structure and the intrusive nature of the diabase.

NORMAL FAULTS PARALLELING THE ANTICLINE

The faults of this group are high-angle normal faults, the largest being in Spring Canyon. (On the map it is designated as Fault No.2.) It has a displacement of 560 feet, strikes N 51°W and dips S 67°W. As can be seen from the map this fault causes the Pioneer shale and the Barnes conglomerate to be repeated.

Another fault of this same type is Fault No. 3 which occurs in the saddle immediately northeast of Helene Peak. It strikes N 38°W and dips N 78°E. Along it the Ruin granite is found on the hanging wall while diabase forms the footwall.

Fault No.4 is the last of the paralleling system. It is in the small canyon immediately west of Nugget Flat, and marks the boudary between the granite and the diabase. Like the other faults of this same group it too is a steeply dipping normal fault. Mine development along it has made it possible to measure this fault more closely than the others. At a point 100 feet east of Newbould's house the vertical displacement is 73 feet while 1400 feet south the displacement is 103 feet. The displacement of the two segments of the McMorris vein shows a horizontal movement that moved the west side northerly for 105 feet.

not entirely a normal fault!

NORMAL FAULTS RADIAL TO THE ANTICLINE

Normal faults trending from S 60°W to N 70°W occur radially to the intruded and faulted anticline. They are best observed along the western rim of Richmond Flat where the Scanlan conglomerate forms a horizon along which it is easy to see faulting. Five faults (Faults No. 6, 7, 8, 9, and 10 of Plate I) were mapped on the western side of Richmond Flat; two others, Faults No. 5 and 11, were mapped in the east central part of the area. In none of the faults of this group is the displacement as great as that of those earlier described. Fault No. 11 as a maximum throw of almost 100 feet, but in Fault No. 10 the total vertical movement has not exceeded 18 feet.

GEOLOGIC HISTORY

The geologic history of Richmond Basin is essentially that of the Globe-Ray region.

The earliest event recorded in the rocks of the Basin is the pre-Apache intrusion of the Ruin granite which here forms the entire basement rock. The intruded formation is believed to be the Pinal schist which forms the basement in many other localities within the Globe-Ray region. In the Richmond Basin, however, the schist is not exposed. With the intrusion there was mountain building, followed by a long period of erosion which eroded all of the overlying formations and wore the granitic mass down to an almost featureless plain.

Now came a new epoch; the land mass of granite became a depositional area. Shallow water bodies must have spread over the land to effect the formation of the Scanlan conglomerate. These waters had very little sorting power for they did not remove the arkosic gravel that overlay the Ruin granite. Along the northwest side of the Basin, and upon the flat south of Richmond Lead there seems to have been a rather broad, gentle depression in which the arkose had accumulated to a greater depth than in the remainder of the area. Here the Scanlan conglomerate is as thick as 15 feet with pebbles sparyingly scattered throughout. The climate of that time may well have been very similar to that of the present, in that the arkose formed at that time seems to be very similar to gravels that are at present forming on the low hills of the area.

The pebbles which occur usually as strata within the arkose are elliptical or even angular showing that they were not subjected to any great amount of mechanical attrition.

The lower member of the shale, which overlies the Scanlan conglomerate, shows by its 265 feet of fine arkosic quartzite that there must have been a landmass capable of yeilding feldspathic material nearby.

Above the lower member of arkosic quartzite is 375 feet of thin-bedded red, purple, and green shales which record the accumulation of sandy silt and mud in waters that were often so shallow that the mud-flats were sometimes marked by ripples, and at other times were left entirely bare so that sun-cracks resulted.

The Barnes conglomerate which lies directly above the Pioneer shale is rather difficult to interpret. Without any noticeable unconformity, its pebbles, six inches and less in diameter, are laid down upon the fine silts of the Pioneer formation. The pebbles and boulders are of quartzite with small amounts of red chert and vein quartz pebbles. Since no unconformity is known, it is thought that the formation represents a time in which the water bodies were advancing causing littoral conditions and the formation of the conglomerate.

Overlying the Barnes conglomerate is some 12 feet of cross-bedded quartzite which contains occasional pebbles; it is followed by 37 feet of shale which contains interlayered sandy beds and pebbles. These suggest that as the water deepened arkosic sands were deposited first; later shale beds show a temporary return of Pioneer conditions.

The Dripping Spring quartzite was next deposited. Its uniform beds of buff and pink arkosic sands indicate by their uniformity, lack of cross-bedding, mud cracks, and ripple marks that it was laid down in deeper water than the Pioneer formation or the conglomerates.

Since the Dripping Spring quartzite is the youngest sedimentary formation present in the Basin, all further geological history must be inferred from the igneous rocks and structure, together with observations of the younger sediments of the neighboring area.

South of the Basin one and a half miles the upper beds of the Dripping Spring quartzite are exposed, and they show by mud cracks, worm casts, and ripple marks that shallow water conditions were returning. In the same locality the impure dolomitic Mescal limestone, which overlies the Dripping Spring quartzite, indicates that it too was laid down in shallow water.

A half-mile farther to the south the Mescal limestone is covered by a basalt flow. Whether this occurred as a subareal or a subaqueous flow is not known, but

(16)
Ransome, in writing of it, says:

> The extent and regularity of the flow, when taken in connection with its relations to the beds below it, show that the surface covered by it had undergone little if any erosion.

After the eruption of this material, the sandy, pebbly, cross-bedded Troy quartzite began to accumulate in the depositional area. The upper part of this formation is the oldest of the sediments in central Arizona to have fossils that are recognizable as such. These definitely place it as Cambrian and marine.

It is probable that this region in common with the Globe region was submerged in Devonian and Carboniferous time and that limestone was deposited at that time. There is no way of dating the diabase from the work done in Richmond Basin, but Dr. Stoyanow (17), who has studied the occurrences throughout the state believes it to be post-Apache and pre-Troy.

good for Stoy

It is difficult to definitely ascribe any particular age to the structures. The anticline was clearly post-Dripping Spring and since it is believed to be pre-diabase, it must also be pre-Troy. The hypothesis of the fault being pre-diabasic is suggested by the fact that the Pioneer formation has been intruded by sills of diabase on the downthrow side of the fault but almost not at all on the upthrow side. The drag on the downthrow side of the fault

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(16) Ransome, F. L., Op. Cit., p.86.

(17) Stoyanow, A. A., Oral communication, May 4,1935.

would have tended to open the sediments along their bedding planes, making for easier ingress of the fluid diabase than on the upthrow side where the fault drag would have tended to close the bedding planes to the solution.

After the diabase intrusion, faulting occurred parallel with it both within the intrusive and in the sediments on either side.

The next event recorded is the volcanic activity that accompanied the andesite porphry. It occurs as a sill in the Dripping Spring quartzite and as a dike in one of the parallel faults in the diabase. This activity is correlated with the andesite flows of the Ray district,(18)

The relative ages of the quartz diorite and the andesite are not known as there is nothing to indicate them. The quartz diorite intruded the same zone of weakness along which the diabase had intruded and in the southeastern part of the area forms a small stock.

Silver bearing vein post dacite?

The ore deposits followed the intrusion of the quartz diorite and andesite porphry. Although the ore deposition is not considered to be directly derived from the quartz diorite in that veins of silver ore occur in it, yet it is thought that the ore solutions were very probably derived from a later phase of the same magma.

oh oh!

Inasmuch as the region to the south is covered by dacite, it may be that dacite also covered the Apache Mountains, but has since been eroded away. Since that time

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(18) Ransome, F. L., Op. Cit. pp. 87-88.

the region has been subjected to active erosion which has removed all the formations above and part of the Dripping Spring quartzite.

ORE DEPOSITS

CHARACTER AND DISTRIBUTION

The ore deposits of the district are of two types. They are:

1. Ore deposits associated with the Scanlan conglomerate.
2. Ore deposits that occur as veins in fault fissures.

Ore Deposits Associated with the Scanlan Conglomerate

General Discussion

It was the silver deposits of this group that first attracted the early prospectors and miners to Richmond Basin, and led to the early production of the district. Erosion has laid bare the mineralized horizon for a considerable area so that the rich mineralization of native silver, argentite and cerargyrite was almost at once apparent to the prospectors when they first entered the Basin. Of Richmond Flat, Nugget Flat, and the flat that lies between them Nugget Flat has been the most productive, it being the location of such rich mines as the Nugget and Lulu which were operated in the seventies and eighties of the last century.

Structure and Texture

Although the entire contact of the granite and Scanlan conglomerate are mineralized to some extent, commercial orebodies are only found where vertical mineralized fissures have intersected the ore horizon.

The ore shoots consist chiefly of quartz and adularia with subordinate amounts of barite. These form a drusy vein matter in which the ore matter is found. The quartz occurs as ordinary crystallized massive quartz, as small crystals lining the vugs, and as lamellar plates which are secondary after calcite. Barite and hematite form a relatively small amount of the gangue. The ore minerals occur disseminated throughout the gangue minerals and also as crystals of cerargyrite and embolite in the vugs. Further discussion of the ore minerals and their occurrence will be given under the heading "Ore Minerals".

Ore Deposits that Occur as Veins in Fault Fissures

General Discussion

The greatest production in Richmond Basin has been from the McMorris, Richmond, Jumbo, and Helene veins or leads.

McMorris Vein

The McMorris vein is an east-west striking vein of banded material which dips 78°N. It can be traced on the surface for almost 3000 feet by the prospect shafts and mines that outline its course. The vein varies from 3 to 5 feet in width where exposed at the surface. The vertical displacement is about 17 feet, but the horizontal component is unknown. As the McMorris mine shaft has not been kept in repair, the nature of the vein at depth had to be inferred from the material on the dump.

This consists of brecciated wall rock in which the interstices are filled by a mixture of hematite and barite. Later mineralizing solutions have introduced quartz and silver metallization which is in part replacing the earlier minerals. The ore that was seen on the dump assayed 19 ounces per ton, but it was only in picked material that silver mineralization was evident.

Richmond Vein

The Richmond vein is a segment of the McMorris vein which has been offset by Fault No.4. On Richmond Flat, the Richmond vein coincides with Fault No.7. Considerable exploration has been done along the fault, but apparently the mineralization was limited.

Jumbo Vein

The Jumbo vein is entirely in the diabase dike that cuts northwesterly across the Basin. The strike of the Jumbo vein closely parallels that of the dike and its dip is N 57°E. That the Jumbo vein also occupies a fault fissure is shown by the difference between the rock of the hanging and foot walls of the vein. The foot wall is made up of a pegmatitic facies of the diabase, while the hanging wall is the usual fine-grained diabase. The mineralization occurs as bands of cerargyrite and argentite in a gangue of barite and quartz, with small amounts of adularia.

Helene Vein

The Helene vein, as well as the Nugget Lead, is in the quartz diorite. The workings on the Helene Vein may be seen on the southwest slope of the peak of that name. They are so badly caved that the nature of the vein and its mineralization was hidden, although copper-stained rock upon the dump indicates the presence of copper ores. Tennantite is the only hypogene sulphide identified.

Nugget Vein

The Nugget Vein, like the Helene, is northeasterly-trending. Inasmuch as Nugget Canyon, which lies directly below the vein, has yielded tens of thousands of dollars in native silver and argentite, the vein is considered the source, although there has never been any direct production from it.

The vein occurs in a southeasterly-dipping fault fissure whose dip is not regular, but takes a step-like form. The movement of the walls has caused enlargement of the horizontal portions of the vein and constriction of the vertical portions, and it is in the enlarged portion that mineralization has occurred. This feature of the vein is best seen in one of the tunnels at the southwestern end of the vein.

The nature of the vein structure suggests that the rich float may well have been derived from one of the horizontal portions of the vein which was productive. The vein in the flat segments of the Nugget Lead is banded massive and amethystine quartz with smaller bands of barite and hematite.

MINERALS OF THE ORE DEPOSITS

Ore Minerals

Native Silver (Ag)

Native silver is one of the chief ore minerals of the district, and has been found as a supergene mineral in every mine in the Basin. It is not definitely known to what depth the native silver is found, but the reports are that it was the chief ore mineral in a spur of the McMorris Vein on the 600-foot level.

Argentite (Ag_2S)

Argentite is one of the most important ore minerals of the Basin. It occurs scattered as blebs throughout the ores of the horizontal group and as one of the constituents of the banded McMorris and Jumbo veins. The argentite is the chief hypogene silver mineral throughout all of the workings examined, with the possible exception of the Helene Mine, where tennantite carries the silver.

One specimen of argentite from Richmond Basin which weighs over 6 pounds is in the Mineral collection of the University of Arizona.

Cerargyrite (AgCl)

Cerargyrite is another very common ore mineral of the Basin. Nearly all of the ores contain some silver chloride, and in some of them the values are almost entirely represented by this mineral. The cerargyrite occurs as coatings on the surfaces and as crystals surrounding the quartz crystals of the small vugs. In the Jumbo Vein cerargyrite was very massive, forming plates some of which were a half inch thick and as large as a man's hand. It was intimately associated with argentite in the banded vein, and with it formed the chief ore minerals of the Jumbo Vein.

Tennantite ($5Cu_2S.2(Cu, Fe,Zn)S.2As_2S_3$)

Small amounts of silver bearing tennantite were found on the dumps from the Helene Vein; one fragment assayed 951 ounces of silver to the ton. As the vein itself was inaccessible, it is not known how the ore occurred.

Chalcopyrite ($CuFeS_2$)

Chalcopyrite occurs sparingly in some of the ore shoots of the horizontal group. However, its occurrence is so limited that it is scarcely noticed unless the ore specimens are very closely examined. Small amounts of this same mineral were found on the dumps of the tunnels which were driven into the hill just west of the andesite porphry dike, and a polished section of the vein hematite showed small amounts of chalcopyrite as veinlets in the hematite.

GANGUE MINERALS

Quartz (SiO_2)

Quartz is the most abundant gangue mineral, both in the vein and in the horizontal deposits. In the horizontal contacts it is either massive or well crystallized amethyst. It is also found as comb structure in small veinlets, and as crystals in small rather tight vugs. In the Nugget and Jumbo veins the quartz occurs as bands or small parallel veinlets penetrating the country rock.

Limonite ($Fe_2O_3 \cdot nH_2O$)

Adularia is another important gangue mineral which is present in considerable amounts in all of the banded ores.

Sericite ($2H_2O \cdot K_2O \cdot 3Al_2O_3 \cdot 6SiO_2$)

Sericite is a gangue mineral in the flat leads, where it forms a yellow-tinted white to rose-tinted rock which, because of its granular texture, is called "sugar quartz" by the miners.

Barite ($BaSO_4$)

Barite is one of the most abundant gangue minerals in the vein type of deposit, and it apparently becomes more abundant with increase in depth. The crystals of barite have a radiating lamellar structure, and are later than the hematite.

Hematite (Fe_2O_3)

Hematite is commonly associated with barite, particularly in the McMorris and Nugget veins. The small cracks or spaces between the lamellae, which were originally filled with hypogene minerals, now often carry silver chloride and argentite. The oxidation and leaching effects of the supergene solutions removed the chalcopyrite and brought about secondary enrichment of the silver.

GENERAL STATEMENT OF MINERALIZATION

A study of the mineralogy of the ore deposits leads one to believe that the solutions which deposited the ores were derived either from some magma which is not represented by the rocks in the Basin, of from a much deeper portion of the quartz diorite than has yet been exposed. These solutions worked up through the fault fissures and out into the permeable Scanlan-arkose zone which was overlain by the relatively impermeable Pioneer shale and the diabase, to ultimately deposit hypogene chalcopyrite, argentite, and tennantite (?) in both the vertical han and horizontal veins. As time went on and the veins were exposed to the action of air and surface waters, the hypogene minerals were dissolved, in part at least, and the copper was carried away. The silver was re-precipitated as the native metal and cerargyrite.

MINERALIZING SOLUTIONS AND PARAGENESIS

The mineralizing solutions[19] as they first issued from the magma reservoir were acid, and, being acid, they first attacked the basic oxides that go to make up the feldspars. CaO and Na_2O were leached from the granite and diorite, causing residual concentration of silica, and Al_2O_3. The silica was deposited as massive quartz, and the

(19) Bowen, N. L., The Broader Story of Magmatic Differentiation Briefly Told: Ore Deposits of the Western States, A.I.M.E., 1933, p. 125.

Al_2O_3 united with the K_2O of orthoclase to form sericite.

As the acidity of the solutions was reduced pyrite and calcite were deposited. Although neither of these minerals is present now, they are attested by pseudomorphs. Quartz and barite both occur as pseudomorphs after calcite; limonite is pseudomorphic after pyrite.

The next stage of mineralization is that of the hematite and barite. The barite occurs as radiating crystals which penetrate the hematite, but it is not known whether the hematite is older.

Following the hematite-barite mineralization came the sulphide ore minerals. These occur as veinlets of chalcopyrite, argentite, and tennantite (?).

There is some suggestion of a later stage of quartz mineralization, but it was not established, as the study of this mineralization is limited by the lack of opportunity and material with which to work.

OXIDATION AND ENRICHMENT

As the ore deposits were brought close to the surface by erosion, they were subjected to the action of downward percolating solutions which caused the formation of cerargyrite and native silver. The oxidation of the pyrite and the chalcopyrite formed H_2SO_4 solutions in the presence of $Fe_2(SO_4)_3$; this solution attacked the silver rich tennantite and argentite. The copper was taken into solution as $CuSO_4$, and the silver became soluble $AgSO_4$. If chlorine was present in the supergene solutions it precipitated the $AgSO_4$ as cerargyrite, but if no chlorine was present, the silver might have been precipitated as native silver by reacting with any sulphide below Ag_2S in the Schurman series. Native silver may also have formed by the action of oxygen upon argentite or perhaps by the interaction between cerargyrite and pre-existing argentite. That this oxidation and enrichment process was very important is evidenced by the fact that all of the mining operations have been conducted in this zone, and that the hypogene ores were apparently too low-grade to be worked commercially.

STRUCTURE AS A GUIDE TO ORE

Ore shoots in the horizon of the Scanlan contact are controlled by mineralized fissures intersecting that horizon. These fissures are difficult to discover and difficult to follow, but they are guides to ore. In general it may be said that the fissures are of two groups: those striking N 75-90°E, and those striking N 0-15°E.

It is somewhat more difficult to outline a control for the veins, and the only control that seems applicable is that due to the simple opening of a fissure by tensional or torsional forces. If the forces were applied in such a way as to make the fissure open, there may be an ore shoot; conversely if the forces operate to close the fissure, the chances for commercial ore are greatly reduced.

Movement in the walls of the Nugget Vein has been of this nature. It is suggested that an inclined shaft on the dip of the vein might reveal an ore shoot on one of the open and mineralized "flats" of the vein.

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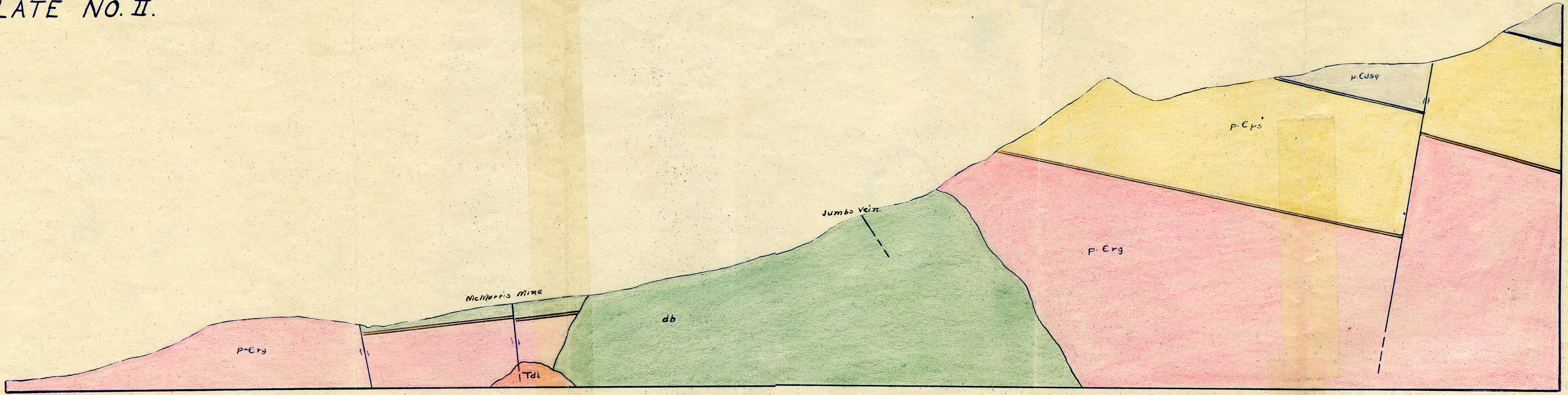
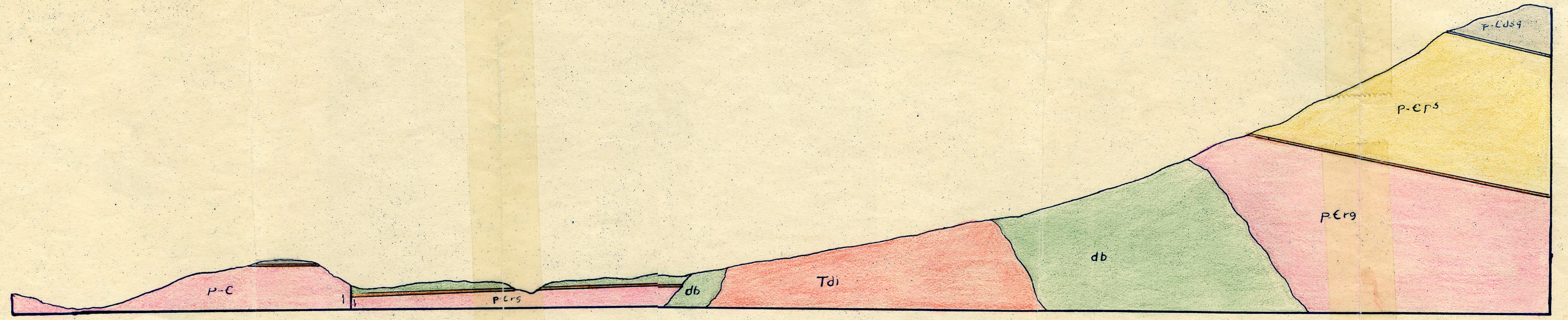
PLATE NO. II.



Section on A-A



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